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(12) ACTAL ROSS MONTAL VISIONAL EUROPEAN PATENT APPLICATION

(43) Date of publication:

23.02.2000 Bulletin 2000/08

(21) Application number: 99114282.9 SONTA-BEDBELL TO NOVER DRAWINGS

(22) Date of filing: 29.07.1999

(51) Int. Cl.⁷: **HO1L 31/18**, HO1L 33/00...

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commission of the present invention. (30) Priority: 18.08.1998 US 135696

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• Rochin, Luis M. greeduor in the intermination of the police of the contract ¿Temeçula; CA 92591;(US) paerour gritiques ineciña and other micromatical devices for instance, these

(74) Representative: dean discoment a language anistaya labindo Schmidt, Steffen J., Dipl.-Ing. . The yell along thems Wuesthoff, & Wuesthoff, Lanual Cope. Although the Cope. Patent-und Rechtsanwälte, and is up beimil of Schweigerstrasse 2 nour about the compart graveing. 81541 München (DE) oc. yldmic in Seremotus inemia रंगला को एक हारा अधिक के नगर का कार्य कार्य कार्य कार्य करा है।

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Figure 4 is 4 op view illustration of a photographic

(54) Semiconductor micro-optical components and method for producing them and resource (8000)

A method for fabricating a monolithic micro-(57) optical component. The construction of the micro-optical components is accomplished by using standard semiconductor fabrication techniques. The method comprises the steps of depositing an etch stop layer (44) onto a semiconductor substrate (42); depositing an optical component layer (46) onto the etch stop layer (44); coating the entire surface of the optical component layer with a photoresist material; applying a photoresist mask (50) to the photoresist material on the optical component layer (46); selectively etching away the optical component layer (46) to form at least one optical column (52); forming a pedestal (54) for each of the optical columns (52) by selectively etching away the etch stop layer (44); and finally polishing each of the optical columns (52), thereby forming monolithic optical components (56). The method may optionally include the step of removing the photoresist mask from each of the optical columns prior to polishing the optical columns, as well as the step of depositing an antireflectivity coating onto each of the optical components.

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EMPODIMENTS

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] This invention relates generally to micro-optical components and, more particularly, to a method for producing monolithic micro-optical components using standard semiconductor fabrication techniques.

2. Discussion of the Related Art

Compact and simple lens systems for micro-100021 optical devices are essential in optical communication systems. Generally, an optical communication system is comprised of independently fabricated micro-optical components that are attached to microbenches. Present optical systems use a variety of techniques for fabricating micro-optical components and for obtaining efficient coupling between micro-optical components and other micro-optical devices. For instance, these optical systems might be manually assembled from very small parts by persons 'tusing' tweezers and a' microscope. Although this manual approach may be feasible for limited quantities of systems; difficulty remains in achieving high output production. On the other hand, current automated assembly techniques fail to achieve the precision alignment and quality needed for most microcomponent systems.

[0003] Therefore, it is desirable to provide a monolithic micro-optical system for use in various optical communication applications. Since there are less individual components to align, the complexity of the assembly process will be decreased. Some assembly steps are entirely eliminated with the formation of a monolithic structure. This reduction in assembly complexity improves alignment accuracy, increases reliability and decreases assembly costs for a micro-optical system. The present invention solves these problems by using standard semiconductor fabrication techniques to manufacture a monolithic micro-optical system.

SUMMARY OF THE INVENTION: 3

[0004] The present invention relates to a method for fabricating monolithic micro-optical components. The construction of the micro-optical components is accomplished by using standard semiconductor fabrication techniques. The method comprises, in one embodiment, the steps of depositing an etch stop layer onto a semiconductor substrate; depositing an optical component layer onto the etch stop layer; coating the entire surface of the optical component layer with a photoresist material; applying a photoresist mask to the photoresist material on the optical component layer; selectively etching away the optical component layer to form at least one optical column; forming a pedestal for

each of the optical columns by selectively etching away the etch stop layer; and finally polishing each of the optical columns, thereby forming monolithic optical components. The method may optionally include the step of removing the photoresist mask from each of the optical columns prior to polishing the optical columns, as well as the step of depositing an antireflectivity coating onto each of the optical components.

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[0005] Other objectives and advantages of the present invention will be apparent to those skilled in the art upon reading the following detailed description and upon reference to the drawings in which the drawings in the drawings in which the drawings in the drawings in which the drawings in the drawings in which the drawings in which the drawings in

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Figure 1 is a perspective view of at micro-optical system having a micro-optical component in accordance with the present invention;

Figure 2 is a top view of a micro-optical duplexer system implementing an exemplary micro-optical component of the present invention; and

Figure 3 is a side view illustration of a semiconductor wafer in accordance with the present invention;

Figure 4 is a top view illustration of a photoresist mask in accordance with the present invention;

Figure 5 is side view illustration of a photoresist mask in accordance with the present invention;

Figure 6 is side view illustration of initial optical columns being-formed by selectively etching away an optical component layer in accordance with the present invention;

Figure 7 is a side view illustration of pedestals being formed by an undercutting etching process in accordance with the present invention;

Figure 8 is a side view illustration of the selectively etched surface of the optical columns, where the photoresist mask has been removed in accordance with the present invention; and

Figure 9 is a side view illustration optical components that have been polished into shape in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED COLUMN OF THE PR

[0006] While the invention is described herein with reference to illustrative embodiments for particular applications, it should be understood that the invention is not limited thereto. Those having ordinary skill in the art and

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access to the teachings provided herein will recognize additional modifications, applications and embodiments within the scope thereof and additional fields in which the present invention would be of significant utility.

[0007] A micro-optical system 10 for use in an optical fiber network application is depicted in Figure 1. Microoptical system 10 is a monolithic structure that is created (as further described below) using standard semiconductor fabrication techniques. Micro-optical system 10 includes an micro-optical component 14 connected 10 by a pedestal 16 to a semiconductor substrate 12. The micro-optical component 14 is shown as a spherical ball. lens, but is intended to represent various optical composinents, such as a cylindrical or conical lens, a concave or convex lens, a prism or any other related optical 15 devices. Each of these components or combinations. thereof serve to focus light or redirect an optical beam between other photonic components (e.g., receivers, transmitters and repeaters) and may be used to construct a micro-optical system. Then de noitainen programme 20 [0008] A micro-optical duplexer 20 is, depicted in Figure 2 as an exemplary implementation of a micro-optical system in an optical fiber network application. Microoptical duplexer 20, is being used as a bi-directional. transceiver, in a fiber network. Micro-optical duplex 20, 25 includes a microbench 30 that is mounted onto a housing 22.(e.g., Kovar, housing), which has a feedthrough for a an optic fiber, 24. Asingle-mode fiber, 24 serves as the connection to a remote fiber network (not shown) a photo diode 26 and laser diode 28 are also mounted to 10,30 housing 22. The tolerances in positioning and fixing an these active devices on housing 22 are on the order of " " (e.g., jnydrebronnie acid deionigiganim [0009] Microbench 30 (4mm x 1,4mm x 1,mm) provides the various passive micro-optical components needed 35 by the system. A right spherical lens 32, a left spherical lens 34 and a wavelength filter 36 are each formed and passively, aligned on microbench, 30. In order to have a collimated laser beam for a distance of several millimeters, these spherical lenses have andiameter on the 10.40 order_of 900 um cTo achieve the high accuracy that is required sfort this passive alignment, microbench (30, not including these micro-optical components tare stabri-is to cated in accordance with the principles of the present out ತಿಸಿಂಗಿಯ್ಯ Once an optical component has been for noitneyni [0010] itadin operation of the duplexer 20, light with the care and collimated by right spherical lens 32 before being and passed through wavefilter 36 and focused onto the end face of the single-mode fiber 24: Light, with the waye 50 length = 1550 nm enters through fiber 24 and is collimated by left spherical lens 34 prior to being reflected at the wavelength, filter, 36, and idetected by photo diode, 26. The While depicting, these micro-optical components in the man context of a micro-optical duplexer, ithis discussion is quite intended, to adequately teach one skilled in the art to to the implement, micro-optical, components, of other presentant invention in a variety of optical applications. The entire beauties

[0011], Figures 3-9 illustrate the steps for fabricating a, micro-optical component of the present invention. Figure 3 shows a side view of a typical semiconductor of wafer 40., Commonly known, epitaxy, techniques (i.e., i.e. LPE, MOCVD, etc.) are used to grow precisely calibrated thin single-crystal semiconductor layers. Ango indium phosphide, (InP) substrate 42 serves as as microbench, for the micro-optical components. A pedestal layer 44 with a thickness on the order of 2-5 microns is deposited onto substrate 42. This layer is comprised. of a ternary material (i.e. lnGaAs or AllnAs) quaternary material (ie., InGaAsP) and determines the pedestal height for each optical component. Using the accuracy... of the epi-crystal growth technology, the pedestal height can be controlled at the angstroms tolerance level. And optical component layer 46 is then deposited onto pedestal layer 44. Optical component layer 46 should be deposited at a thickness correlating to the maximum required lens dimensions (at least 20 microns thick) the Indium phosphide (InP) is also chosen for optical comon ponent layer 46 because of its etching characteristics as well as its ability to form a high index lens with low aberusinglioptica, columns 32 are those in Figure 6. As will [0012] Joln an alternative preferred embodiment athe optical component layer, 46, and substrate, 42 may, be comprised of gallium arsenide (GaAs), whereas the pedestal layer, 44 sis somprised of aluminum gallium on arsenide (AlGaAs), clt is important to note that sother and materials can be used for these various layers, For s example, the optical component layer 46 and substrate or 42 may be any III-V semiconductor material and mayour include, cindium phosphide (InP), gallium, arsenide, yo (GaAs), indium arsenide (InAs) and gallium phosphidebo! (GaP). Moreover, although two different materials have to ing similar thermal expansion coefficients may be used, the same material is preferably used for both optical, to component layer 46 and microbench substrate: 42. (In 30) this way optical alignment problems caused by thermal, ... expansion are minimized in optical applications where wide temperature variations are common (i.e., in milistac tary and space applications). or bayonae attachases at at [0013] Photolithography and other known wafer fabriage cation techniques are then used to fabricate the optical to components. First, a photoresist coating is applied over the the entire surface of the optical component layer 46 and The preferred photoresist material is 2-ethoxpyethylace-ioc tate (60%) and n-butyl acetate (5%) in xylene; and hexauc. amethyldisilozane (HDMS) because of its suitability for to q use in the dry etching of deep profiles on indium phos-ex phide (InP), and related semiconductor materials. Phothics toresist material may also include 2-ethoxyethylacetate + n-butyl acetate in xylene solvent, 2-ethoxyethylace tate + n-butyl acetatenin xylene, and silicon dioxide (SiO₂) precoated, 2-ethoxyethylacetate: +(n-butyl ace-; 5v. tate in xylene and silicon nitride (Si₃N₄) precoated; silizion con dioxide (SiO₂) and complex silicon, nitride (Si_xN_y); were or aluminum oxide (Al₂Q₃) precoated attraction bearing and [0014]: A-mask is used to transfer a lens pattern onto to x: 20) Erropose live rus and behavor of analysis en of elect a

the optical component layer. Lens patterns are chosen based on the quantity and type of lens required for a particular optical application. As will be apparent to one skilled in the art, an initial lens shape is dependent on the particular mask design. Depending on the type of optical component (e.g., spherical ball lens, cylindrical ball lens, conical ball lens, convex lens, concave lens, prism, or a combination of these components), a corresponding mask will be used to establish the shape of the initial optical column. As best seen in Figure 4, a 10 mask is a pattern in which the regions to be exposed are opaque and the protected regions are shaded. The mask is alighed with optical component layer 46 such " that when the photoresist material is exposed to an ultraviolet (UV) light source through the mask, the 15 appropriate lens pattern is transferred onto the surface of the optical component layer. As a result, a photoresist mask 50, as illustrated in Figure 5, is formed on the surface of optical component layer 46. Her sent and the layer [0015] LENext, initial optical columns for each of the micro-optical components is formed by dry etching away the unwanted optical component material. These initial optical columns 52 are shown in Figure 6. As will be apparent to one skilled in the art, electron cyclotron resonance (ECR) etching, binductive couple plasma 25 (ICP) etching or reactive-ion etching (RIE) are commonly employed dry etching techniques. Dry etch mixtures may include argon and hydrochloric acid (Ar/HCI), argon hydrogen and chlorine (AR/Cl2/H2), argon and hydróbromic acid (Ar/HBr), argón and bromine (Ar/Br₂), 30 argon and chlorine (Ar/Cl2), argon and methane and hydrogen (Ar/CH₄/H₂), methyl iodide (H₃Cl), bromine iodide (IBr), methane and hydrogen and sulfur fluoride (CH₄/H₂/SF₆);^a fethŷl iodide (C₂H₅I), i isoèthŷl iodide (C₃H₇I), hexaflüoride carbon and hydrogen(C₂F₆/H₂), 35 or dichlorodifluoro carbon and oxygen (CClafa/Oa). [0016] Referring to Figure 7, wet selective etching with controlled undercutting will provide a pedestal support or stem 54 for each of these optical columns. By using a -selective (quaternary) etching solution, pedestal layer 40 44 is selectively removed from underneath the optical columns without reffecting the binary or other material comprising the optical columns and substrate layer. Moreover, this undercutting etching approach provides " sufficient/space below each of the optical columns for 45 polishing fand subsequent formation of the optical components. Wet selective etching chemicals may include potassium នៃ potassium si pota water (KOH: K3Fe(CN)6:H2O); lactic acid: nitric acid (1000) CH3CH2OCOOH:HNO3) hydrochloric acid:nitric acid 50 (HClimannion in the house in the control of the con peroxide:deionized water (H3PO4:H2O2: 81:H2O), nitric acid (HNO₃); sülfuric acid:hydrogen peroxide:deionized wateros 1/(HaSO4:HaOa:HaO); (Xanitric) 1 acid:tartaric 1/2 acid:deionized and (and all epinwaters in the entire (nemss HNO3:HOO@(@H5O)5@OOH:H5O? where in between 1 100 and 10) and hydrofluoric acid:hydrogen peroxide:deionized water (HF:H2O2:n H2O) wherein between 1 and

[0017] After the above-described etching process, the photoresist coating is removed from the optical component layer in Figure 8. Using acetone, the photoresist mask is removed from the surface of the optical columns. Following the removal of the photoresist mask, the acetone is removed from the surface of the optical columns with isopropanol and then the isopropanol is removed from the surface of the optical columns using deionized water. The photoresist can also be removed using photoresist stripper, potássium hydroxide, or other equivalent alkaline chemicals followed by a delonized water rinse. Finally, oxides and photoresist residues faire removed from the surface vor the optical columns using potassium hydroxide (KOH). S. , 2091 X9 11... [0018] Lastily, these optical columns are further etched and polished into optical components 56 as seen in Fig-1 ure 9: A selective wet etching process continues the formation process of an optical component For instance) a weak non-orientation binary selective etching solution (e.g., hydrofloric acid hydrobromic acid (1HF:10HBr); hydrobromic lacid: acetic lacid laci hydrochloric citabilitae acid propylene acid propylene acid propylene (HCI:CH3CHOHCH2OH)) can be used to polish and round off the edges and corners of the optical column. Since this solution will etch the corners and edges faster than other portions of the optical columns, the corners are rounded off to form lenses, thereby shaping the optical columns into optical components lit should also be noted 'that this solution should not etch the guaternary material of the pedestalse in Palatebag ant to lairatem [0019] Furthermore, a weak chemical polishing solution (e.g., hydrobromic acid:acetic acid:deionized - water(n HBr:CH3COOH:H20, where n between and and 4). Propertie shydrochloric solicacid: propylenesq siglycol s (HCI:CH3CHOHCH2OH)) can be used to polish the sure faces of an optical column? In this case; polishing is usually performed at a very low temperature, typically as between 10 degrees and 20 degrees centigrade! To polish the surface of optical lens, emerge the water which 'contains' the formed lens into the polishing solutor tion, agitate the wafer for a calibrated period of time and then rinse in deionized water. Allow water to dry before proceeding to the remaining steps !!! ๑๐๓๑๒๐๐๐๑ การ [0020] Once an optical component has been formed, [0020] an antireflectivity of filtering coating can also be applied with to any one of these optical components to maximize transmitted light. For the present invention, afficity stal mixture of antireflectivity (AR) coating which contains magnesium (fluoride (MgF), aluminum oxide (AlpO), aluminum oxide (AlpO), aluminum oxide hafnium fluoride (HfF), Silicon dioxide (SiO2), and silicon nitride (Si₃N₄) is deposited over the entire sufface of each optical component. This coating may be applied by? using electron beam evaporation, sputtering, chemical in it vapor deposition, or other similar processes in similar processes in similar processes. [0021] The foregoing discloses and describes merely exemplary embodiments of the present invention. One skilled in the art will readily recognize from such discus*20* ,

sion, and from the accompanying drawings and claims, that various changes, modifications and variations can be made therein without departing from the spirit and scope of the present invention.

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1. Amethod for fabricating a micro-optical component, comprising the steps of the step of the s

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selectively etching away said optical composelectively etching away said optical column;
nent layer to form at least one optical column;
forming a pedestal for each of said optical columns by selectively etching away, said etch
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occupility of said optical columns, thereby
the forming monolithic optical components.

The method of Claim 1 HOOD HO 1811 1916W

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depositing an antireflectivity coating onto each to a fight; and/or wherein an area bias

at least one of said optical components being selected from the group consisting of a spherical ball lens, a cylindrical ball lens, a conical ball lens, a convex lens, a concave lens and a

prism, and/or time he provided to deta entrance said optical components and usaid substrate nonbeing comprised of material, having substantable in the said similar, thermal expansion coefficients for improving action client and/or

improving optical alignment, and/or nocestalisaid, optical components, layer, and; said, substrate, being comprised of a material selected of a material selecte

said optical components layer comprises a layer at least 20 microns thick, and/or said etch stop layer being comprised of a material selected from the group consisting of indium gallium arsenide phosphide (InGaAsP) and aluminum egallium, arsenide (AlGaAs),

no tand/orab level mean gold labrado unatida said etch stop layer comprises, a layer at least 2 the step of selectively etching away, said optical component layer further comprises drycetching in the areas surrounding said photoresist mask to form at least one optical column using at least one of electron cyclotron resonance (ECR) etching, inductive couple plasma (ICP) etching and reactive ion etching (RIE), and/or said etch stop layer being comprised of a quaternary semiconductor material and the step of forming a pedestal further comprises applying a selective quaternary etch to said etch stop layer, and/or the step of polishing further comprises selective step of polishing further comprises selective step of polishing further comprises selective.

the step of polishing further comprises selectively wet etching the surface of said optical components at a temperature in the order of a pull to 20 degrees centigrade.

3. A method of fabricating micro optical components on a semiconductor substrate comprising the steps of:

(AlGA) a bindeor's phinesis multiple steps of:

said etch stop layer comorises a layer at least 2 - nosimas, entropy, jayer, opino, jayer, entropy, en

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c (photoresist material liamaxed bus analyx and providing a mask such that a patternitor said state mask determines the quantity and shape of the providing to optical components for med on, said opti-

aligning said mask to said optical component layer of photoresist material;

exposing the surface of said optical component layer with the layer of photoresist material to a photoresist mask of said optical compose selectively etching away, said optical compose

incoresistrimask to form; at least one optical (4) column; stance entrupe (2013)

forming a pedestal for each of said optical collision umns by applying a selective etch to said etch at a stop layer and the rest the normal

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BING Polishing each of said optical components: A)

4. ¿The methodof Claim 3 further comprising the step of applying an antireflectivity coating onto each of said optical components (to maximize transmitted light, and/or wherein one noduce ablantation

at least one of said optical_components; being selected from the group consisting of a spheri-

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9 ^c cal ball lens, a cylindrical ball lens, a conical 10 10 90 ballilens falconvex lens, a concave lens and a Enableprism? and/ordensity of the consulting 'said' optical' components and said substrate being comprised of material having substan- 5 fram tially similar thermal expansion coefficients for improving optical alignment, and/or said optical components layer and said substrate being comprised of a material selected Trom the group consisting of indium phosphide 🍅 😘 (InP), 📆 gầi liữm Tầr sể nidê (GàAs), Indiùm arsenide (ÎnAs) l'and gallium iphosphide (GaP), and/or said optical scomponents layer comprises a ayer at least 20 microns thick, and/or TO 10 said etch stop layer being comprised of a material selected from the foroup consisting of indium gallium arsenide phosphide (InGaAsP), atrendium Gallium Arsenide (InGaAs), Aluminum aceta Indium Arsenide (AllnAs), and aluminum gallium arsenide (AlGaAs), and/or said etch stop layer comprises a layer at least 2 -กิจาก microns-thick, and/orte กราย กลากกับอยกลา the step of coating said optical component layer fürther comprises providing said photoresist material selected from the group consisting F Thyof 2-ethoxyethylacetate 4 n-butyl acetate in xylene and hexamethyldisilozane (HDMS), 2-

ાદર [†]@thoxyethylacetate માંગ-butyl acetate in જ્ઞાene adi lo solvent, 2-ethoxyethylacetate + n-butylacetate in xylene and silicon dioxide (SiO5) precoated, 2-ethoxyethylacetate 194/8 n-bûtÿli acetate in Transylene and silicon nitride (Si3N4) precoated, sil-Cancicon dioxide (SiO2) and complex silicon nitride (Si_xN_v); rand caluminum coxide (Al₂O₃) pre-ानगर coated; and/or se to appired ent unitalities

the step of selectively etching away said optical component layer further comprises dry etching in the areas surrounding said photoresist mask to form at least one optical column using at de least one dof leléctron cyclotron résonance (ECR) etching, inductive couple plasma (ICP) etching and reactive-ion etching (RIE), and/or the step of selectively etching away said optical component layer further comprises using a dry *** etch mixture selected from the group consisting and hof argon and hydrochloric acid (Ar/HCI), argon hydrogen and chlorine (Ar/Cl₂/H₂), argon and 💛 finydrobromic acid (Ar/Hbr), argon and bromine (Ar/Br), argon and chlorine (Ar/Cl2), argon and methane and hydrogen (Ar/CH₄/H₂), methyl ਕੜਾਣ iódide (HaCl) porómine iödide (lbra), 'metháne io coand hydrogen and sulfur flouride (CH4/H2/SF6), Performantion of the first think in the first think is a second of the first think in the first think is a second of the first think in the first think is a second of the first think in the first think is a second of the first think in the first think in the first think is a second of the first think in the first think in the first think is a second of the first think in the first think is a second of the first think in the first think is a second of the first think in the first thi hexaflouride carbon and hydrogen (C₂F₆/H₂), and dichlorodifluoro carbon and oxygen emer(@GBF3/O3),Pand/or Diffe to has the de de de la compete de la comp

prises using a selective wet etching material selected from the group consisting of potassium hydroxyde:potassium ferricyanide:deionized water (KOH: K3Fe(CN)6:H2O), lactic (CH₃CH₂OCOOH:HNO₃), acid:nitric acid hydrochloric acid:nitric acid (HCI:HNO₃), phosphoric acid:hydrogen peroxide:deionized water (H₃PO₄:H₂O₂:H₂O), nitric acid (HNO₃); sulfuric peroxide:deionized latir water acid:hydrogen $(H_2SO_4:H_2O_2:H_2O),$ acid:tartaric nitric acid:deionized a total of the telephone water (HNO₃:HOOC(CH₂O)₂COOH:H₂O) iotal to and hydroflüöric acid:hydrogen peroxide:deionized water (HF:H₂O₂:H₂O), and/or^{che do a de a} 'said etch stop layer being comprised of a quaternary semiconductor material and the step of forming a pedestal further comprises applying a selective quaternary etch to said etch stop layer, and/or sa yawa chidor yievitoelee the step of polishing further comprises using a selective wet polishing solution selected from the group consisting of hydrofloric acidihydrobromic acid (HF:10 HBr), 18 hydrobromic acid:acetic acid (HBr:CH3COOH) hydrochloric acid:propylene glycol (HCl:CH3CHOHCH2OH) and hydrobromic acid:acetic acid:deionized water (HBr:CH3COOH:H2O); and/or of the continue of the continu said step of removing said photoresist mask and cleaning the exposed surface of said optical columns further comprises the steps of:

removing said photoresist mask using a The phospition of acetone, the the product removing said acetone from the surface of said optical columns using isopropanol; र भार्ने व्यक्तिलेशांगेष्ठी said lisopropanol from the surand in face of said optical columns using deion-का 'त्राच्या izëd watër; and/orlivo a लाका uad lao call lens, a convex lens, a concrete long a c

columns promo polishing said optical collection

the step of applying an antireflectivity coating fürther comprises using a coating process selected from the group consisting of electron beam evaporation, sputtering and chemical vapor deposition; and/or legitou gaivorgan the step of applying an antireflectivity coating 🚈 furthér comprisés dépositing at leastfone layer Trof antireflectivity coating containing magnesium fluoride (MgF); aluminum oxide (AloO3), hafnium-flouride (HfF); silicon dióxide (SiO2), and silicon nitride (Si₃N₄). raid obrisal components layer comprises

5. A micro-optical system for optical signal processing, comprising make of the many apple does also हात्राहास्य व्यवकृत्वा सामा सन्दर्भात्र । स a semiconductor substrate; courtes mouth a an foptical componentabeing formed from an epitaxial optical component layer depositéd on said substrate; and so reverse to the result of the

a pedestal coupling said optical component to said substrate being formed from a stop etch layer, said stop etch layer being interposed between said optical component layer and said substrate.

The micro-optical_system of Claim 5_wherein_

- microns thick.

said optical component being selected from the group consisting of a spherical ball lens, a cylindrical ball lens, a conical ball lens, a convex lens, a concave lens and a prism, and/or said optical components and said substrate being comprised of material having substantially similar thermal expansion coefficients for -15. improving optical alignment, and/or said optical components layer and said substrate being comprised of a material selected from the group consisting of indium phosphide (InP), gallium arsenide (GaAs), indium arse- 20 nide (InAs) and gallium phosphide (GaP), and/or said optical components layer comprises a layer at least 20 microns thick, and/or said etch stop layer being comprised of a material selected from the group consisting of indium gallium arsenide phosphide (InGaAsP), aluminum gallium arsenide (AlGaAs), and Indium Gallium Arsenide (InGaAs), and/or

12 12 M said etch stop layer comprises a layer at least 2

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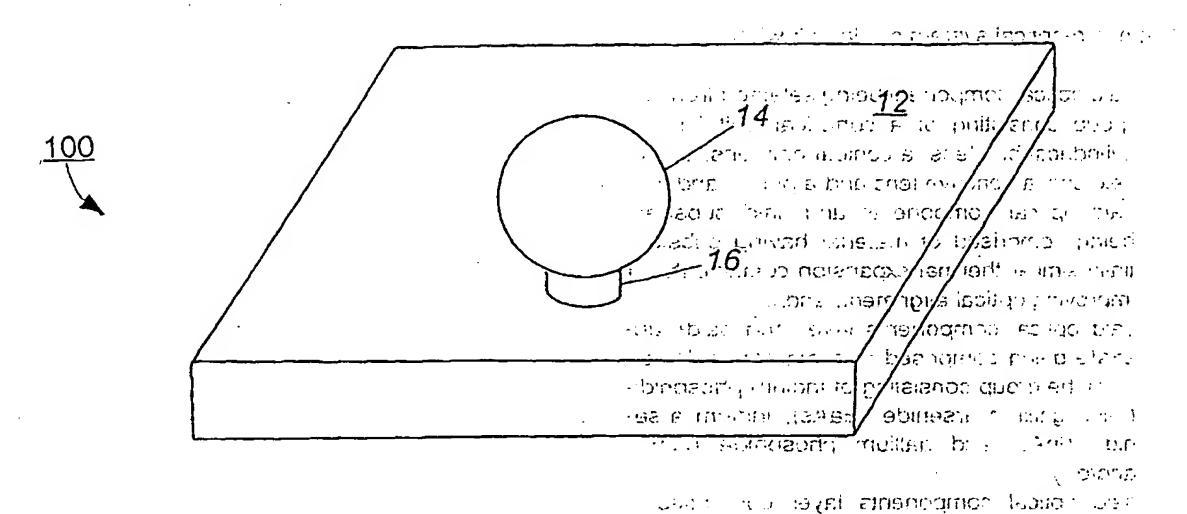


Figure 1

eyer releast alt material, and/or are compresed to the comprese compresed to the comprese compresed to the c

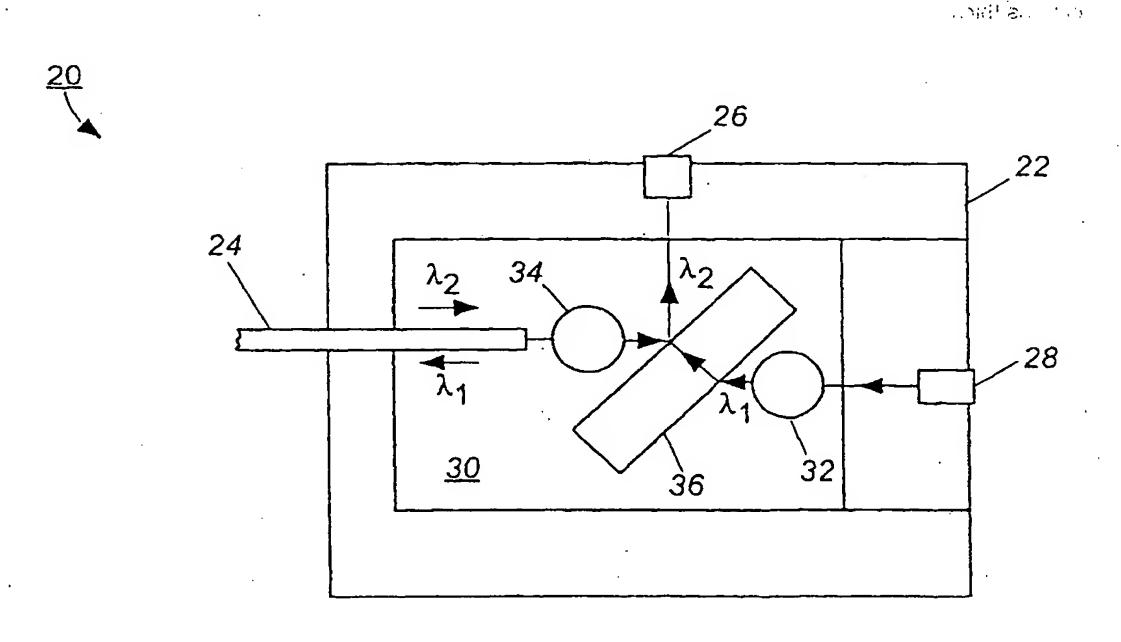


Figure 2

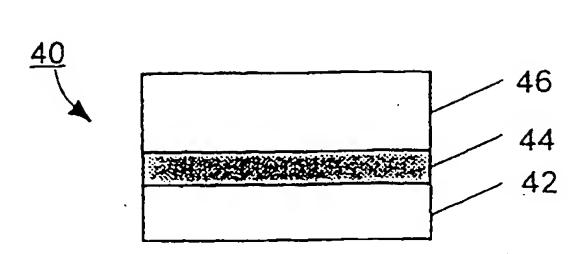


Figure 3

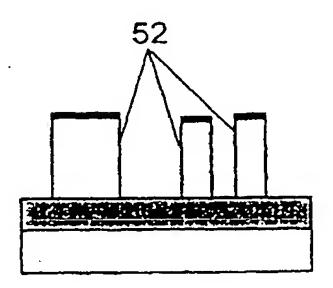


Figure 6

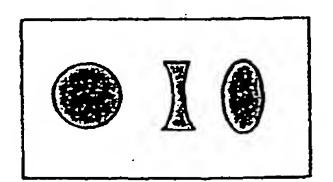


Figure 4

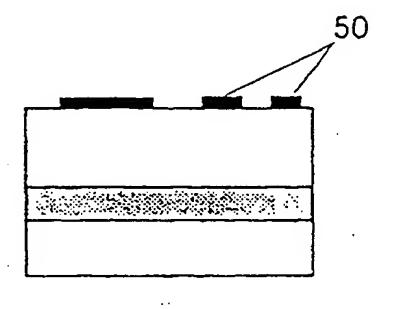


Figure 5

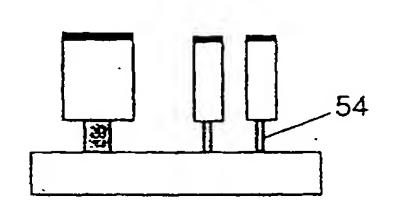


Figure 7

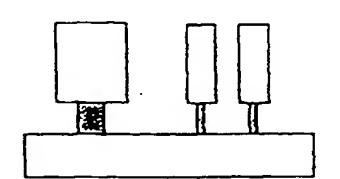


Figure 8

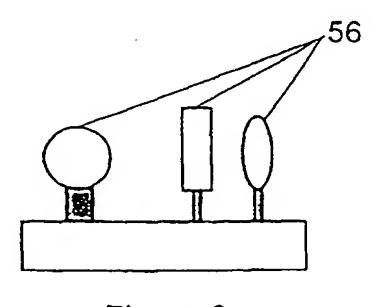


Figure 9